Title of The Invention

METHOD AND EQUIPMENT FOR DETECTING PATTERN DEFECT

Background of The Invention

The present invention relates to a method and equipment for detecting a pattern defect, and more specifically relates to a method and equipment for detecting a pattern defect that are suitable to test a defect of a pattern formed in a semiconductor wafer, a liquid crystal display, a photomask, etc.

Conventionally, such kind of detecting equipment, as described in Japanese Published Unexamined Patent Application No. 7-318326 (prior art No. 1), detects an image of a pattern under test (hereinafter referred to as "test pattern" for simplicity) with an imager such as a line sensor etc. and recognize a nonconformity as a defect by comparing grayscale levels of the detected image signal to an image signal delayed by a prescribed time while moving the test pattern.

Moreover, for a conventional technology concerning detection of a defect of a test pattern, Japanese Published Unexamined Patent Application No. 8-320294 (prior art No. 2) is already known. This prior art 2 is intended to be applied for such a test pattern on a semiconductor wafer etc. where a high density area of test pattern such as a memory mat part etc. and a low density area of test pattern such as a peripheral circuit etc.

exist in a mixed manner. In that literature described is a technology comprising the step of: converting a digital image signal that is obtained through AD conversion of an image signal detected from the above-described test pattern into a grayscale so that the brightness or the contrast ranging between the high density area and the low density area of test pattern is converted into a predetermined relation based on a brightness-frequency relationship of the above-described detected image signal; performing function approximation of both the image signal thus grayscale converted and an image signal to be compared (hereinafter referred to as a "comparison image signal") therewith which was also grayscale converted; integrating difference of the two curves represented by the function approximations; aligning two image signals which were grayscale converted based on information of high-precision detection of misalignment obtained from the integral value; and detecting a minute defect with high-precision by comparing test patterns while keeping the alignment between two image signals optimally.

Moreover, in the case of detecting of a photomask, conventionally there is an idea that light used in the detecting should be the same as exposure light so as to detect only a detrimental defect which will cause trouble in actual exposure, accordingly a prior art has also been disclosed that inspection of a photomask exposed with ultraviolet light (hereinafter referred to as "UV light") was performed using the same UV light

as the exposure light. For patent applications concerning this technology, as a technology to test the appearance of a circuit pattern on a photomask, there is Japanese Published Unexamined Patent Application No. 8-94338 (prior art No. 3) and No. 10-78668 (prior art No. 4), etc.

In addition, as a technology to measure the amount of phase shift in a phase shift mask, there is Japanese Published Unexamined Patent Application No. 10-62258 (prior art No. 5) and No. 10-78648 (prior art No. 6), etc.

Furthermore, as a technology to clearly visualize a circuit pattern and a foreign material optically by inspecting a specimen with visible light and UV light by making good use of a fact that materials used in a process have different absorption characteristics for visible light and UV light, there is Japanese Published Unexamined Patent Application No. 4-165641 (prior art No. 7) and No. 4-282441 (prior art No. 8), etc.

Moreover, as means for measuring optically an external form of an object exist an interferometer. Regarding this, there is Japanese Published Unexamined Patent Application No. 4-357407 (prior art No. 9) wherein UV light is applied to the interferometer.

LSI fabrication in recent years advances toward finer microfabrication in circuit patterns formed on wafers in response to needs of high-integration and the width of a pattern (feature size) as small as 0. 25 μm or less is being required, reaching

almost a limit of imaging optical systems. Therefore, efforts to attain high NA in an imaging optical system and apply the optical superresolution technology as well as efforts to sophisticate image processing are being made. The above-described prior arts 1 and 2 are ones that use those results. However, implementation of high NA has already reached its physical limit and this measure has a problem of weakness for patterns having a large pattern step height. Also, the optical superresolution technology and sophistication of image processing have a problem of limited applicability because of their non-linear response.

Therefore, an attempt to shorten the wavelength of light used in defect detection, from a visible radiation region in conventional use to a UV light region, is an essential approach.

On the other hand, the idea that the same light source as exposure light should be used, which has been originally devised for a photomask, is effective for prior arts 5 and 6 for measuring the amount of phase shift. This is because the amount of phase shift is directly linked with the wavelength of a light source. However, in case defects are to be detected by detecting appearance of a whole surface of a test sample or a large area of a circuit pattern comparable to it, the technology wherein a wavelength of detecting light is chosen to be the same as the exposure light (prior arts 3 and 4) is not necessarily an appropriate technique.

This is because pattern transfer capability by exposure cannot be determined only by a wavelength of a light source and conditions of an optical system. The transfer capability is closely connected with various factors complicatedly, such as the amount of exposure, properties of a resist, the amount of defocusing, an optical characteristic of an underlying material, a developing process, etc. Consequently, the prior arts 3 and 4 are suitable to analyze carefully the pattern transfer capability of a single defect by performing simulation including these complicated conditions, but are different from a technology for detecting defects of a large number of circuit patterns in a short period of time.

In the case where a large number of circuit patterns are examined in a short time, it will be a practical solution for this problem to thoroughly detect any defects having a possibility of being transferred as a detectable defect with sensitivity as high as possible by means of a light source that is chosen only to detect defects rather than performing a detection by applying an expensive, hard-to-handle exposure light source.

In this case, since UV light is employed to improve the resolution, visible light that deteriorates the resolution cannot be employed jointly as is the case of the prior arts 7 and 8.

Further, since it is essential to perform a rapid detecting, minutely converged laser beam as in the prior art 9

cannot be used. In the UV light region, since high-illuminance discharge lamp does not exist, a high-illuminance illumination by means of a laser is dispensable. However, as a result, when a laser beam is expanded to a whole field of view, an interference fringe pattern due to interference of the laser beam, so-called a speckle pattern, occurs and overshoot and undershoot occur in edge portions of a circuit pattern, which make it impossible to obtain images.

Laser beams have excellent features as light sources. To use them in a way of giving their features full play, when a certain area is illuminated, generally the laser beams are used to perform scanning with some kinds of scanning means.

For the scanning means, there are means capable of scanning by driving a mirror mechanically to change a reflection direction, means capable of scanning by giving an electric signal to an optical crystal to effect change in diffraction direction or in refraction direction, and the like.

Among the former means exist a galvano mirror, a polygon mirror (a polyhedron mirror), etc. and among the latter means exist an A/O deflector, an E/O deflector, etc.

In Japanese Published Unexamined Patent Application No. 7-201703 disclosed is equipment to scan a laser beam using a polygon mirror or a galvano mirror and write a pattern with a minutely converged laser spot. Further, in Japanese Published Unexamined Patent Application No. 8-15630 disclosed is equipment

to scan a laser beam using a polygon mirror or an A/O deflector and write a pattern with a minutely converged laser spot. Furthermore, in Japanese Published Unexamined Patent Application No. 10-142538 disclosed is equipment to write a pattern with a minutely converged laser spot in a scheme where two polygon mirrors are set in synchronization with each other, a phase difference of half the period between mirror facets being set, to perform the scanning and further these polygon mirrors are switched one another, so that a combination of polygon mirrors scans a laser beam with improved efficiency. Furthermore, in Japanese Published Unexamined Patent Application No. 7-197011 disclosed is a device wherein two polygon mirrors are stacked up with a phase difference of half the period between mirror facets thereof being set and a semiconductor laser diode is modulated in synchronization with its rotation. Furthermore, in Japanese Published Unexamined Patent Application No. 5-34621 disclosed is a device wherein mirror facet angles of a polygon mirror are varied from facet to facet, so that two-dimensional beam scanning can be performed.

The scanning by a polygon mirror (polyhedron mirror) has a problem that since the scanning is performed under continuous rotation, the scanning is unavailable at edges of mirror facets, effective scanning time is decreased, and as a result decrease in efficiency is brought about.

Moreover, if high-speed scanning is intended, a plurality of polygon mirrors cannot be rotated in synchronization with each other because of its continuos rotation. Therefore it is impossible in a high-speed region that: a two-dimensional area is scanned by integrating polygon mirrors; and scanning efficiency of polygon mirrors is improved in a scheme where two polygon mirrors are used to perform the scanning in synchronization with each other, also with a phase difference of half the period between mirror facets thereof being set, and switched over for use as disclosed in Japanese Published Unexamined Patent Application No. 10-142538.

Further, a method for directly modulating a laser, even in a scheme where two polygon mirrors are stacked up with a phase difference of half the period between mirror facets thereof being set, as disclosed in Japanese Published Unexamined Patent Application No. 7-197011, is not suitable for application in a deep ultraviolet wavelength region. Because gas lasers and solid state lasers are not suitable for the direct modulation. Further because one piece of such laser is too expensive to make a configuration where a plurality of lasers are arranged and on-off switched in stead of direct modulation.

Further, since a polygon mirrors rotates continuously, scanning range cannot be changed. Therefore a shape of the scanning range by a polygon mirrors is limited to rectangular

shapes and hence polygon mirrors are not suitable to scan circular regions.

Further, in the wavelength region of deep ultraviolet light sources, there is a problem that surface irregularity of a polygon mirror causes scattered light, which deteriorates beam quality and refection efficiency.

As for the scanning by galvano mirrors, ordinary galvano mirrors can only perform low-speed scanning whose scanning speed is few hundreds Hz at maximum, whereas resonant-type galvano mirror can perform high-speed scanning of a few kHz but a driving signal is limited only to sinusoidal waves and scanning angle varies sinusoidally, and therefore the scanning speed of a beam is not constant. Because of this fact, when laser beam scanning is performed for illumination to obtain a detected signal especially using a storage-type sensor, there is a problem that a signal from a slowly scanned area is relatively large, whereas a signal from a fast scanned area is relatively small.

For E/O deflectors, there is no crystal usable in a wavelength range of ultraviolet to deep ultraviolet. Therefore current technology cannot respond to a request for a high-resolution optical system with a light source whose wavelength is shortened.

Moreover, for A/O deflectors there is only quartz for a crystal usable in the range of ultraviolet to deep ultraviolet. However, acoustic velocity in quartz is large. This fact is not

a large obstacle when an A/O element is used as a modulator, but becomes a problem when used as a deflector. When a diffraction grating is formed in quartz using an acoustic element, variation of a spacing between the gratings in response to a change of signal frequency applied to the acoustic element is small because of its large acoustic speed.

This means that an angular region in which a deflector can deflect light is small. Since the acoustic velocity in quartz is about 6000m/s and an upper limit of signal frequency that can be applied to an acoustic element usable to this is around 150 MHz, deflection of only 0. 23 degree is achievable provided that a variation range of frequency is ±100 MHz. Therefore if a sufficient scanning range is intended to be achieved, an extremely long optical path (1 m or more) should be provided. With a long optical path provided, there arises a problem of deterioration in beam position and beam quality due to environmental change such as fluctuation of air in the optical path.

Summary of The Invention

It is an object of the present invention to provide a method and equipment for detecting a minute circuit pattern rapidly with high resolution in order to solve the above-mentioned problems.

In addition, it is another object of the present invention to provide defect detecting equipment capable of detecting defects such as submicroscopic foreign particles, a pattern defect, etc. by scanning a short-wavelength (ranging from ultraviolet to deep ultraviolet) laser beam for illumination over a test object such as a semiconductor wafer etc. at a high speed with high efficiency and detecting an optical image of the test object.

To achieve the above-mentioned objects, the present invention adopts the following steps of: employing a UV laser source as a light source; setting up means for suppressing occurrence of the speckle pattern of the UV laser beam in an optical path; and detecting an image of an object by illuminating surface of the object with the UV light whose coherence was reduced.

More specifically, as this means for suppressing the occurrence of the speckle pattern of the UV laser beam, one of the following means is intended to be provided: (1) means for converging rays of light from a light source onto a single point on a pupil of an objective lens and scanning the light thus focused on the pupil in exact timing with a storage time of a detector; (2) means for making UV light emitted from the laser source go into a bundle of fibers, each fiber of which is intentionally misaligned to the UV light, and converging rays of light going out of the bundle of fibers onto the pupil of the objective lens;

(3) means for making the light going into a group of fibers, each of which has a different length varied by the amount of the coherence length of the laser source or more to other fibers, and converging rays of light going out of the group of the fibers onto the pupil of the objective lens; and (4) means for illuminating the pupil with a combination of above means.

In other words, the present invention provides pattern defect detecting equipment characterized by comprising: laser source means for emitting an ultraviolet laser beam; coherence reducing means for reducing the coherence of the ultraviolet laser beam emitted from this laser source means; irradiating means for irradiating a sample with the ultraviolet laser beam whose coherence was reduced by the coherence reducing means; image detecting means for detecting an image of the sample irradiated with the ultraviolet laser beam from this irradiating means; and defect detecting means for detecting a defect of a pattern formed on the sample based on information concerning the image of the sample detected with this image detecting means.

Further, the present invention provides a method for detecting a pattern defect characterized by comprising the steps of: emitting a laser beam whose wavelength is not longer than 400 nm from a laser source; irradiating a sample with the emitted laser beam through coherence reducing means; detecting an image of the sample irradiated with this laser beam; and detecting a

defect of a pattern formed on the sample based on information concerning this image of the sample detected.

Further, to achieve the above-mentioned object, the present invention adopts a configuration wherein a set of polygon mirrors which are made up by stacking a purity of polygon mirrors with phase of mirror facets thereof mutually shifted is rotated, a laser beam is modulated through an A/O modulator in synchronization with rotation of the above-mentioned polygon mirrors and switched to either of polygon mirrors appropriately to perform the scanning for irradiation, so that the object can be scanned at a high speed with high efficiency even when employing a short-wavelength laser beam that is dispensable to realize high-resolution.

Brief Description of The Drawings

FIG. 1 is a configuration diagram showing a first embodiment of pattern defect detecting equipment for a test pattern according to the present invention.

FIG. 2 is a diagram illustrating an emission spectrum of a discharge tube illumination.

FIG. 3 is a diagram showing illumination condition on the pupil of the detecting objective lens and that in the field of view, both by the discharge tube illumination.

FIG. 4 is a diagram showing illumination condition on the pupil of the detecting objective lens and that in the field of

view, both by laser beam illumination, and also showing a pattern in the field of view and a detected signal from it.

FIG. 5 is a diagram showing illumination condition on the pupil of the detecting objective lens and that in the field of view, both by laser beam illumination expanded on the pupil.

FIG. 6 is a diagram showing illumination condition on the pupil of the detecting objective lens and that in the field of view, both by laser beam illumination according to the present invention.

FIG. 7 is a diagram showing a relationship between a CCD image sensor detector and an illuminated region in the field of view.

FIG. 8 is a diagram showing a relationship between the CCD image sensor detector and the illuminated region in the field of view to improve the illuminance.

FIG. 9 is a diagram showing the CCD image sensor and illumination condition on the pupil of the detecting objective lens and those in the field of view, both by laser beam illumination according to the present invention.

FIG. 10 is a diagram showing a TDI image sensor and illumination condition on the pupil of the detecting objective lens and those in the field of view, both by laser beam illumination according to the present invention.

FIG. 11 through FIG. 15 are diagrams schematically showing contrivances that reduce the spatial coherence of laser beam illumination according to the present invention.

FIG. 16 is a configuration diagram showing a first embodiment of a laser beam scanning mechanism according to the present invention.

FIG. 17 is a configuration diagram showing a second embodiment of the laser beam scanning mechanism according to the present invention.

FIG. 18 is a configuration diagram showing a third embodiment of the laser beam scanning mechanism according to the present invention.

FIG. 19 is a diagram illustrating a configuration of an irregular-type polygon mirror applied in the third embodiment.

FIG. 20 is a diagram illustrating condition of the reflected light reflected from the polygon mirror.

FIG. 21 is a configuration diagram showing a fourth embodiment of the laser beam scanning mechanism according to the present invention.

FIG. 22 is a configuration diagram showing a fifth embodiment of the laser beam scanning mechanism according to the present invention.

FIG. 23 and FIG. 24 are configuration diagrams showing a variant and another variant of the fifth embodiment of the laser

beam scanning mechanism according to the present invention, respectively.

FIG. 25 is a configuration diagram showing a sixth embodiment of the laser beam scanning mechanism according to the present invention.

FIG. 26 and FIG. 27 are configuration diagrams showing a variant and another variant of this sixth embodiment, respectively.

FIG. 28 is a configuration diagram showing another embodiment of the laser beam scanning mechanism according to the present invention.

FIG. 29 is a configuration diagram showing a second embodiment of the pattern defect detecting equipment equipped with the laser beam scanning mechanism according to the present invention.

FIG. 30 is a configuration diagram showing a signal processing system in the pattern defect detecting equipment shown in FIG. 29.

Description of The Preferred Embodiments

Referring to the drawings, a first embodiment of a method and equipment for detecting a pattern defect of a test pattern according to the present invention will be described. FIG. 1 is a block diagram showing a first embodiment of pattern defect detecting equipment according to the present invention. Numeral

2 is an X, Y, Z, and θ (rotation) stage, on which a semiconductor wafer 1, an example of a test pattern, is mounted. Numeral 7 is an objective lens. Numeral 3 is an illumination light source (UV laser source) for illuminating the semiconductor wafer 1, which is an example of a test pattern. Numeral 5 is a polarizing beam splitter, which is constructed so as to reflect the illumination light from the illuminating light source 3, make it pass through the objective lens 7, and perform bright field illumination on the semiconductor wafer 1. Numeral 6 is a quarter wavelength plate, which constructs a high-efficiency half mirror in conjunction with the polarizing beam splitter 5. Numeral 4 is a scanning mechanism for scanning a laser beam from the light source over the pupil of the objective lens 7. Numeral 8 is an image sensor for outputting a grayscale image signal according to the brightness (grayscale) of reflected light from the semiconductor wafer 1, which is an example of a test pattern. Numeral 9 is an AD converter for converting the grayscale image signal obtained from the image sensor 8 into a digital image signal.

While the stage 2 is being moved in a scanning mode and the semiconductor wafer 1, which is an example of the test pattern, is being moved at a constant speed, information of the illuminance (grayscale image signal) of the test pattern formed on the semiconductor wafer 1 is detected with the image sensor 8.

Numeral 10 is a grayscale converter for performing such grayscale conversion as is described in Unexamined Japanese Patent Application No. 8-320294 on the digital image signal outputted from the AD converter 9. In other words, the grayscale converter 10 compensates an image where unevenness of the illuminance occurred due to thin film interference of the illumination light caused by a thin film formed on the semiconductor wafer by the process through performing logarithmic conversion, index transform, polynomial transform, etc. The grayscale converter 10 is configured so as to output a digital signal in, for example, 8 bits. Numeral 11 is a delay memory for storing and delaying an output image signal from the grayscale converter 10 by the amount of 1 cell or plural cell pitch, or 1 chip, or 1 shot, wherein a pattern on a semiconductor wafer comprises a plurality of these pattern units.

Numeral 12 is a comparator for detecting a defect by comparing the image signal outputted from the grayscale converter 10, on which the grayscale conversion was performed, to a delayed image signal obtained from the delay memory 11.

The comparator 12 is used to compare an image outputted from the delay memory 11 that was delayed by an amount corresponding to a cell pitch etc. to a detected image. By inputting coordinates of arrangement data etc. on the semiconductor wafer 1 beforehand, which are obtained based on design information, using an inputting means 15 consisting of a

key board, a disk drive, etc., CPU 13 makes defect test data from results of comparison by the comparator based on inputted coordinates of array data etc. on the semiconductor wafer 1 and stores them in a storage device 14. These defect test data can be displayed on display means such as display etc. according to need and also can be outputted in means for outputting.

By the way, detail of the comparator may be as is described in Japanese Published Unexamined Patent Application No. 61-212708: for example, the comparator may comprises an image alignment circuit, a difference image detecting circuit for aligned images, a nonconformity detecting circuit for performing a binary coded processing on the difference image, a feature extracting circuit for calculating areas, lengths (projected length), coordinates, etc. from binarized outputs, and the like.

Next, the light source 3 will be described. As described above, in order to attain high resolution, it is necessary to employ a light source of a shorter wavelength. However in wavelength regions of UV light (ultraviolet light) and DUV light (deep ultraviolet light), where that effect can be maximized, it is rather difficult to have such illumination with high illuminance. Regarding UV light sources, a discharge lamp is excellent. Especially, a mercury xenon lamp has a stronger emission line in the UV region than other discharge lamps.

FIG. 2 is a diagram showing an example of a relationship of radiant intensity versus wavelength for a mercury xenon lamp,

indicating that emission lines in the DUV region occupy only 1-2 % of total amount of radiation, which makes a contrast to a wide wavelength region of visible light in conventional use (i. e. occupying about 30 % of total amount of radiation). In addition, light emitted from a discharge lamp, whose radiation is not oriented in a particular direction, can be guided onto a sample with a significantly small efficiency even in the case of a carefully-designed optical system. After all a sufficient amount of light can hardly be secured with illumination of a discharge lamp in the UV region.

Moreover, when a discharge lamp having a large output is employed with the intention to improve the intensity of illumination (the illuminance), since such a lamp only has a only larger size of a luminescent spot of radiation compared to those having a small output, after all the illuminance (light power per unit area) cannot be improved with such a scheme.

Consequently, it can be rightly thought that an effective, high-illuminance illumination is optimally performed by a laser source whose center wavelength is in the UV region or in the DUV region (hereinafter UV is used to indicate these two regions) which is not longer than 400 nm, preferably not longer than 300 nm. The present invention provides means for solving the problem in concern when this UV laser is employed as a light source to illuminate the sample.

FIG. 3 is a diagram showing illumination condition of the pupil of the objective lens and that in the field of view of the sample when illuminated by normal white light. In the figure, AS denotes the pupil, FS the field of view. At a position of the pupil, an image 31 of the light source is formed; at a position of the field of view, an almost uniformly illuminated area 32 comparable to the whole field of view is formed.

Next, FIG. 4 is a diagram showing illumination condition of the pupil of the objective lens and that of the field of view of the sample when illuminated by a laser source. In this case, the image of the light source 41 at the position of the pupil reduces to a point. A circuit pattern illuminated by illumination 42 in the filed of view on the sample creates, for example, an image having such a detection waveform as d) in FIG. 4 for a pattern whose cross section is as shown in c) in the figure.

As can be seen from the figure, an origin of a fact that the overshoot and undershoot occur in edge portions of a circuit pattern and a speckle pattern occurs when a circuit pattern is illuminated by a laser beam and its image is taken in is that σ of the illumination is small. In other words, this can be that illumination is not performed from various angles in the filed of view on the sample under the objective lens. On the contrary, in a normal white light illumination, illumination having a certain size of its image on the pupil is performed, and illumination is performed in the field of view on the sample from

all directions lying in an angle comparable to NA (the numerical aperture) of the objective lens.

For any coherent light (light having the coherence) such as a laser beam, σ (depending on an image size of a light source on the pupil) is zero. This is because that for coherent light, an image of its light source is a point, and therefore an image on the pupil is also a point. It goes without saying that, as shown in FIG. 5, using a different lens system, an enlarged beam of light 51 is made to project on the pupil. However, since a laser beam has the coherence, after all obtained is the similar result 52 as is obtained for a case that all the beam goes out of a point where σ =0, accordingly the problem cannot be solved. Therefore, means for reducing the coherence of a laser beam is prerequisite. Reducing the coherence needs to reduce either the temporal coherence or the spatial coherence.

In view of this, the present invention proposes a method wherein firstly, an image of the light source is formed on the pupil of the objective lens of detecting equipment, and then the image is illuminated on the sample through the objective lens in such a manner, for example, that first a point 61 in FIG. 6 a) is illuminated, second a point 62, third a point 63, … to achieve substantial illumination 65 all over the field of view. During this process, the speckle pattern and an image of the overshoot and undershoot can be obtained at each location, but respective images are not coherent to one another because these were obtained

at different times. Therefore, if these images are summed up on the detector, the same image can be obtained as is obtained by an incoherent light source after all. To perform the summation on the detector, a storage-type detector such as the CCD image sensor is suitable.

In this case, a scanning scheme may be spiral scanning 66 and television-like (raster) scanning 67, as shown in b) and c) in the same figure, and any other scanning, as long as the whole field of view is scanned. However, it goes without saying that the scanning should be completed within a storage time of a detector. Therefore, it is recommendable that the scanning should be performed in synchronization with operation of the detector.

In this way, an image by illumination 65 covering the whole filed of view as shown in a) FS of FIG. 6 can be obtained.

Further, not shown in the drawings, the same effect as that of this scheme can be obtained through the steps of: making up a secondary light source consisting of a plurality of point light sources by inserting a fly-eye lens in an optical path of a UV laser beam emitted from a laser source; forming an image of this secondary light source consisting of a plurality of the point light sources on the pupil of the above-described objective lens; and varying a position of this image of the secondary light source temporarily on the pupil of the objective lens.

Here, a case will be considered where a one-dimensional image sensor (for example, a solid state imager such as the CCD

image sensor etc.) is used that is a storage-type detector and that is advantageous in scanning rapidly the test sample in the whole area of a narrow field of view such as that of a microscope. As shown in FIG. 7, when the whole area of the field of view is illuminated for a one-dimensional image sensor 71, illumination contributing to detection is only that in area 72, whereas that in area 73 occupying major portion of the optical power does not contribute to detection at all. To improve the illuminance, it is desirable to perform linear illumination as an area 82 to the one-dimensional image sensor 71, as shown in FIG. 8. (A two-dimensional image can be obtained by scanning the CCD image sensor in a direction perpendicular to an alignment direction of elements of a sensor array thereof.)

In that case, by performing illumination whose longitudinal direction is set in the Y-direction as shown in FIG. 9 (a longitudinal direction of an area 91 shown by a bold solid line in the figure), illumination 92 adjusted to a shape of the CCD image sensor 71 can be performed. Also, the scanning on the pupil is performed in the X-direction. In this case, its scanning period T_s should be shorter than the storage time T_i of the CCD image sensor. Through this procedure, summation of images can be done. A problem associated with this scanning scheme is that, since the illumination has some spread in the Y-direction on the pupil from the beginning, it is impossible to scan in the Y-direction. Consequently, the overshoot and undershoot occur in

the Y-direction of the CCD image sensor in the field of view cannot be reduced. On the contrary, if a length of the illumination in the Y-direction is shortened with the intention to scan in the Y-direction on the pupil, the width of the illumination in the Y-direction become wider in the field of view and hence the illuminance decreases.

Against this problem, the present invention uses a Time Delay Integration Image sensor (hereinafter referred to as a "TDI image sensor") and solves the problem. The TDI image sensor, which is one of the CCD image sensors, has a structure that a plurality of one-dimensional image sensors are arranged in two dimensions and is of such a type that the amount of light is intentionally increased by delaying, by a prescribed time, an output of each one-dimensional image sensor which takes a picture at a position and then adding it to an output of an adjacent one-dimensional image sensor which takes a picture at the same position. In the case of the TDI image sensor, since N stages of the CCD image sensors (N equals to few tens to one hundred) are aligned in the field of view, even if the width of area illuminated in the field of view is widened by N times, illumination light is utilized effectively for detection.

Because of this fact, the length of converged rays of light 102 in the Y-direction on the pupil can be reduced to approximately 1/N times the length of the case of the CCD image sensor, and the scanning can be performed both in the X-direction

and in the Y-direction on the pupil. Consequently, the overshoot and undershoot occurring both in the X-direction and in the Y-direction of the TDI image sensors on the pupil can be reduced, and hence excellent detected images can be obtained.

Moreover, the scan period T_s on the pupil only needs to be shorter than N times the storage time of one stage of the TDI image sensor. However, considering the illuminance distribution generated in the field of view, in order to attain much uniform detection, it is desirable that T_s should be shorter than a half of N times T_i.

Moreover, to perform uniform illumination in the field of view, it is desirable that rays of light from a laser source should be converged after passing through a fly-eye lens or an integrator rather than these rays are converged directly onto the pupil.

Next, means for reducing the spatial coherence will be described. To reduce the spatial coherence, it is only necessary to prepare a plurality of beams of light passing through optical paths whose lengths are mutually different by the amount larger than the coherence length. More specifically, if output light of a laser is made to go into a bundle of a plurality of fibers 11 or glass rods, each of which has a mutually different length, as shown in FIG. 11, output light from such device become incoherent light (having no coherence). If these lights are arranged on the pupil, respectively, an image free from the overshoot and undershoot and the speckle can be obtained.

In addition, it is desirable with this scheme that the coherence length of the laser source should be shorter. For this end, laser beam having an oscillation spectrum with a plurality of longitudinal modes and hence a wide wavelength band $\Delta\lambda_2$ of emission wavelength, as shown in FIG. 11 b), is more suitable than a laser beam having an oscillation spectrum with a single longitudinal mode and hence narrow wavelength band $\Delta\lambda_1$, as shown in FIG. 11 a).

Furthermore, regarding other contrivance for reducing the spatial coherence, there is a scheme utilizing a phenomenon that, when light is coupled to a misaligned fiber, lateral modes of outgoing light (spatial distribution and optical intensity I to a space) vary from that of a fiber with no misalignment. Normally, such variation of modes is regarded as an unfavorable phenomenon in industrial applications, and generally efforts to reduce the variation of lateral modes have been exerted. However, in the present invention, taking advantage of this phenomenon other way, light from a laser is coupled to a plurality of fibers 1210 with their optical axes intentionally misaligned to generate outgoing light a), b), c), d), e) …… having different distributions of lateral modes, as shown in FIG. 12. As a result, since outgoing beams of light thus obtained becomes mutually incoherent, these beams are arranged on the pupil.

FIG. 13 is a diagram showing a condition where emitted light from a laser source 3 is divided into two beams of light

133 and 134 having polarization planes perpendicular to each other by a polarizing beam splitter 131. Numeral 132 is a mirror for deflecting the light into a different direction.

Since two beams of light having mutually perpendicular planes of polarization are mutually incoherent, beams of incoherent light can be obtained with an optical system of a very simple configuration. With this scheme, only two beams of incoherent light can be obtained. However, if this scheme is combined with already-mentioned methods, light with virtually zero coherence can be easily obtained.

Further, since mutually independent light sources are incoherent, independent light sources 141, 142, 143, 144, ... may be used, as they are, to illuminate respective points on the pupil of the objective lens 7, as shown in FIG. 14.

Furthermore, if this method is used in conjunction with the aforesaid method with the polarizing beam splitter, an effect that laser sources are substantially doubled in number can be obtained, as shown in FIG. 15. Moreover, if the number of beams is maintained to the same as before, the number of laser sources can be reduced to the half, and hence a cost can be held down.

In the foregoing, a plurality of means for reducing the coherence of UV laser beam, illuminating a plurality of points on the pupil with this UV laser beam with reduced coherence, and obtaining an image by converging rays of light with the objective lens are described. Each of these means can be used jointly with

other means. Moreover, any other means for reducing the coherence equivalent to these means may be used.

Moreover, although not shown in the drawings, a scheme where a diffuser is inserted on the way of an optical path of a UV laser beam and this diffuser is rotated or reciprocated may be used to reduce both the spatial coherence and the temporal coherence of the UV laser beam at the same time. Further, this diffuser can be used in conjunction with other coherence reducing means mentioned above.

As a scanning mechanism 4 of a laser beam indicated in FIG. 1, an arrangement shown in FIG. 16 through FIG. 28, which will be described below, may be adopted. Firstly, referring to FIG. 16, a first embodiment of the laser beam scanning mechanism according to the present invention will be described. That is, in the first embodiment, polygon mirrors 108 and 109 are stacked up with a rotation phase difference of half the period between respective mirror facets thereof being set and the stack thus made is configured to be rotatable by a rotating motor 101. The polygon mirrors 108 and 109 are mirrors of the mutually identical shape and their effective scanning time ratio is approximately 50 % (Here, the unavailable time is defined as a time when a laser beam hits an edge part of each mirror facet of the polygon mirror and thereby specula reflection cannot be exerted, whereas the available time is defined as a time when the laser beam hits flat plane to exert specula reflection. The available scanning time

ratio is given by the ratio of the available scanning time to a total time.). Further, each polygon mirror is fixed on a spindle of the rotating motor 101 in such a manner that mirror facets comprising one polygon mirror are set with a rotational phase of half the period shifted to corresponding mirror facets comprising the other polygon mirror.

At the same tome, each of these polygon mirrors 108 and 109 are irradiated with a laser beam 104 from a laser source (not shown in the drawings) through an A/O modulator 105. An A/O modulator 105 switches the laser beam into either of irradiation paths 106 and 107 based on a control signal generated by a rotation position-mirror switching signal converter 103 from an output 102 transmitted from an encoder attached to the rotating motor 101. In case two polygon mirrors are switched over, if first order light (for example, light 107) and zero-th order light (for example, light 106) from the A/O modulator 105 are used, the switching can be done by only the single A/O modulator 105 and it is convenient. It should be understood that since just switching an optical path is needed, any means other than A/O modulators may be used. That is, during the available scanning time of the polygon mirror 109, the optical path in use is switched to the optical path 107, and during the unavailable scanning time of the polygon mirror 109, the optical path in use is switched to the path 106. By this scheme, the available scanning time ratio of this polygon mirror system reaches approximately 100%.

Therefore, even when a laser other than an easy-to-modulate semiconductor laser is used and a polygon mirror which has a high scanning speed and hence a low available scanning time ratio of about 50%, highly-efficient and high-speed scanning of a laser beam can be performed.

If the number of stage of polygon mirrors to be stacked is increased, this scheme can be applied for a polygon whose available scanning time ratio is shorter than 50%. In this case, two or more polygon mirrors are stacked up wherein mirror facets comprising each polygon mirror are shifted by one n-th times the period (where n denotes the number of the polygon mirrors) with respect to mirror facets of other polygon mirrors.

By the way, in this configuration provided is an optical system (for example, a lens system) 110 having both: a function of a lens system 112 capable of scanning two laser beams, which are reflected from the polygon mirrors 108 and 109 respectively, along with the same scanning line on an object (in case such a defect as minute foreign particles, a minute pattern defect, etc. is examined, the object will be a test object); and a function of a F-θ lens 111 capable of scanning both laser beams with the same scanning speed.

Next, referring to FIG. 17, a second embodiment of the laser beam scanning mechanism according to the present invention will be described. The second embodiment comprises, as shown in FIG. 17(a), a polygon mirrors 201 and a polygon mirrors 202 which

have different numbers of mirror facets to each other and are stacked up. Because of this configuration, each scanning angle range (i. e. angle range in which reflected light is scanned), which is inversely proportional to the number of mirror facets, is different from that of the other polygon. However, diameters of the polygon mirrors 201 and 202 are determined so that a period of time required for each angle range to be scanned is the same to each other.

This configuration provides a scanning scheme, in case the object 204 of a circular shape, for example a semiconductor wafer, is moved in a direction indicated by an arrow 205 in the figure (on the plane of the figure) and the scanning is performed with polygon mirrors in a direction perpendicular to the direction of the arrow, in a section 208 where a small scanning angle is sufficient, the A/O modulator 105 scans, for example, the zero-th order diffraction light 206 using the polygon mirror 202, whereas in a section 209 where a large scanning angle is necessary, the A/O modulator 105 scans, for example, the first order diffraction light 207 instead using the polygon mirror 201 as shown in FIG. 17(b).

With the use of this second configuration, a time necessary to scan the whole surface of the object 204 can be reduced compared to that of a configuration wherein the scanning is performed with the same scanning angle only suitable for the area 209.

Here, a configuration using two kinds of polygon mirrors is described. However, it is well understood that if much more kinds of mirrors are used, highly- sophisticated illumination with higher efficiency can be performed. Moreover, since timing necessary for switching each polygon mirror is not so delicate, it is not necessary to detect angle from an encoder attached to the rotating motor 101 and rotate polygon mirrors synchronously. Thus, polygon mirrors 201 and 202 may be rotated using respective motors.

By the way, also in this second configuration provided is an optical system (for example, a lens system) 110 having both: a function of a lens system 112 capable of illuminating the same scanning line on the object (in case a defect such as minute foreign particles, a minute pattern defect, etc. is examined, the object will be a test object) with a laser beam reflected by either of the polygon mirrors 201 and 202; and a function of the F-θ lens 111 capable of scanning with the identical scanning speed.

Next, referring to FIG. 18 and FIG. 19, a third embodiment of the laser beam scanning mechanism according to the present invention will be described. By the way, in case the scan object 204 of a laser beam is of a circular shape such as a semiconductor wafer, if a laser beam is scanned simply over a rectangular shape circumscribing the circle with respect to the said scan object 204, the laser beam inevitably scans outside the object area and hence the efficiency of irradiation goes down. In view of this

fact, this third embodiment adopts a polygon mirror 300a, as shown in FIG. 18(a) (FIG. 18(a) is a top view of the polygon mirror 300a), wherein angles $\theta 7$ to $\theta 1$ and $\theta 1$ to $\theta 7$ subtended by respective mirror facets 307a to 301a and 301a to 307a (namely, lengths of mirror facets along its circumference) are varied, respectively, and hence scanning range (scanning length) on the object L7 to L1 and L1 to L7 can be varied when the laser beam 104 (106, 107; 206, 207) is reflected.

By the way, in case a laser beam 210 of, for example, a slit shape or spot shape is scanned, as indicated by L7 to L1 and L1 to L7, over the scan object 204 of a circular shape such as a semiconductor wafer as shown in FIG. 18(b), since it is generally necessary to scan the object along equally spaced lines toward the Y-direction, a subtended angle by each mirror facet can be determined in such a manner that the object of a circular shape is scanned over its whole surface while the polygon mirror is rotated at least one revolution, even if a stage (not shown in the drawings) on which the object 204 is mounted is translated intermittently toward the Y-direction. By the way, if the laser beam 210 is shaped in a slit form, a linear image sensor composed of the CCD image sensor, or the TDI image sensor, or the like can be used as a detector.

Moreover, as shown in FIG. 19, a polygon mirror 300b may be configured so that mirror facets 307b to 301b and 301b to 307b have different inclined angles $\alpha 7$ to $\alpha 1$ and $\alpha 1$ to $\alpha 7$, which are

varied gradually, with respect to a rotation axis, and hence, for example, the slit-like or spot-like laser beam 210 can be scanned two-dimensionally over the object 204 of a circular shape, as shown in FIG. 18(b). Further, numerals L1 to L7 indicate scanning lines done by mirror facets 301b to 307b in FIG. 18(b).

Therefore, in the case of the polygon mirror 300b, it is not necessary to translate a stage with the object 204 of a circular shape mounted on it in the Y-direction. However, when the object 204 is irradiated with the laser beam 210, positing of the laser beam 210 is necessary.

In addition, this third embodiment can be applied to either of the above-described first and second embodiments.

Next, referring to FIG. 20 and FIG. 21, a fourth embodiment of the laser beam scanning mechanism according to the present invention will be described. A polygon mirror 601 shown in FIG. 21 is manufactured by cutting a block of aluminum, its alloy, or beryllium. Mirror facets of the polygon mirror 601 thus manufactured are occasionally of insufficient profile irregularity (plane roughness) when being irradiated with a laser beam 602 whose wavelength is not longer than those of ultraviolet rays. FIG. 20 is an illustration showing a reflected beam in this case projected on a screen. As shown in FIG. 20, when the profile irregularity of the mirror facet is insufficient, there occurs scattered light 502 in the periphery of a specula reflection beam of light 501 from the mirror facet. An experiment carried out by

the inventors has revealed that when the plane roughness of the mirror facet is controlled to be equal to 50Å or less, the amount of scattered light 502, namely the fraction of the light lost, is reduced to 5 % or less of the total amount of reflected light.

Since the scattered light 502 deteriorates the beam quality, it is desirable to remove it as much as possible. In view of this, a fourth embodiment is configured so as to remove the scattered light 502 by providing a scattered light trap 603 (for example, a plate with a hole through which only the specula reflection beam 501 passes.) In this way, by providing the scattered light trap 603, the quality of the scanning laser beam can be improved through removing the component of the scattered light 502 not only in the case of the surface roughness more than 50Å but also in the case of that not more than 50Å.

By the way, the larger the clearance between the mirror facet of the polygon mirror and the scattered light trap 603, the better the performance of trapping of the scattered light 502. An experiment carried out by the inventors has revealed that the clearance of about 1 m can give satisfactory trapping performance.

The fourth embodiment described above can also be applied to either of the above-described first, second, and third embodiments.

Next, referring to FIG. 20 to FIG. 24, a fifth embodiment of the laser beam scanning mechanism according to the present

invention will be described. The fifth embodiment is constructed basically using a galvano mirror. Ordinary galvano mirrors can only perform slow scanning whose scanning frequency lies in the range up to a few hundreds Hz at the best. However, a resonant-type galvano mirror, which is also called as a resonant galvano mirror, can perform the scanning in the rage of few kHz or more, but reportedly a driving signal must be only sinusoidal waves. Therefore scan angle varies sinusoidally and the scanning speed of the beam cannot be constant.

Accordingly, when the laser beam 104 is scanned for illumination over the object 204 mounted on the stage 130 using a resonant-type galvano mirror, called as a resonant galvano mirror, and an image signal is obtained from an image of the object 204 by using a sensor, especially a storage-type sensor, for example the TDI image sensor, the intensity of the image signal from an area being slowly scanned is relatively large, whereas that from an area being fast scanned is relatively small because of varying scanning speed of the laser beam.

In view of this, the fifth embodiment, as shown in FIG. 22, has a construction comprising a resonant-type galvano mirror (resonance operation-type mirror scanner), which is also called as a resonant galvano mirror, wherein a scanning mirror 702 is driven by an actuator 701 based on a sinusoidal driving signal 711 obtained from a sinusoidal signal source 703, and a computer 705 thereof reads a direction of the mirror from an encoder 704

attached to the actuator 701, finds the scanning speed at the point where the scanning angle is read from the scanning angle thus read, and generates a control signal. Further, the computer 705 controls an A/O modulator 706 based on a control signal 710 indicating the scanning speed. Specifically, when the scanning is slow, the transmittance is decreased in proportion to it, whereas when the scanning is fast, the transmittance is increased, so that the quantity of light of a laser beam 707 which is made to hit the mirror 702 is being varied. As a result, even if the scanning speed of the laser beam wherewith the object 204 is irradiated varies, the object mounted on the stage 130 is irradiated with the laser beam 140 with an intensity corresponding to the scanning speed and hence the intensity of an image obtained from the object 204 becomes constant, accordingly a value of detected signal (image signal) becomes constant when detected by a detector 801, for example a storage-type sensor, as shown in FIG. 23. By the way, numeral 121 is a half mirror and numeral 122 an objective lens.

Moreover, control of the laser beam using the A/O modulator 706 may be provided after the reflection other than before the reflection. However, in the case of after-reflection scanning, a laser beam is scanned instead.

Moreover, in the fifth embodiment, as shown in FIG. 23, means to change the amplification ratio in order to control the detected signal (image signal) detected from the detector 801

based on the control signal 710 indicating the scanning speed which is outputted from the computer 705 can give a detected signal (image signal) 803 having a constant strength even when the scanning speed of the laser beam 140 wherewith the object 204 is irradiated varies.

Further, in the configuration shown in FIG. 23, the A/O modulator 706 is assumed to be used in a configuration as shown in FIG. 22 and therefore description of the A/O modulator 706 is omitted. However, other modulating means capable of controlling the intensity of the laser beam in response to the scanning speed may be used without the use of the A/O modulator 706 even when the scanning speed of the laser beam wherewith the object 204 is irradiated varies.

Moreover, since the direction of the mirror 702 varies with a constant phase delay with respect to the sinusoidal driving signal 711 from the driving signal source 703, the control signal 710 to be used for controlling the above-described transmittance and amplification factor may be a control signal from a computer 901 which performs calculation so as to give a phase difference to the driving signal 711 itself, as shown in FIG. 24, other than an output from the encoder 704, as shown in FIG. 22 and FIG. 23.

The fifth embodiment described above is a scheme for keeping detected output constant electrically, and hence this method basically introduces loss and reduces the efficiency.

Therefore, it is desirable to realize the scanning with a constant speed optically.

Next, referring FIG. 25 to FIG. 27, a sixth embodiment of the laser scanning mechanism according to the present invention will be described. The sixth embodiment in FIG. 25 is a case where a lenslike optical element 720 is used. In the resonant scanner 701 (i. e. resonant operation-type mirror scanner), a beam after reflection has a slow scanning speed (i. e. the variation of deflection angle per unit time is small) at an angular position giving a large deflection angle, whereas the beam has a fast scanning speed (i. e. the variation of deflection angle per unit time is large) at an angular position giving a small deflection angle. In view of this, a curved surface of the lenslike optical element 720 is formed so as to have a larger curvature with increasing distance from the center so that at an angular position giving a larger deflection angle, the defection angle becomes further larger according to the deflection angle.

In the sixth embodiment, FIG. 26 shows a case where reflection direction is modified using a bundle fiber 1101 in stead of the lenslike optical element 720. In this bundle fiber 1101, outer fibers have a larger degree of outward inclination to make a larger angle of deflection in accordance with a position of fiber on the exit side thereof than an inner fiber.

In the sixth embodiment, FIG. 27 shows a case where reflection direction is modified to convert the direction using

a holographic plate (or a deflective element) 1201 in stead of the lenslike optical element 720. This holographic plate 1201 is formed so as to have a grating whose spacing becomes narrower with increasing distance from a center so that the outgoing beam from the mirror which passed through the holographic plate 1201 at a position nearer to its periphery suffers larger deflection.

The foregoing is a description of embodiments regarding a resonant galvano mirror. However, these embodiments can be constructed with any of other resonant operation-type mirrors.

As described above, A/O deflectors can generate only a small amount of scanning angle, but their high-speed scanning capability and ease of control remain attractive as before. In case such an A/O defector is used, to attain a necessary scanning range with a minute scanning angle, it is necessary to secure a long optical path after light goes out. However, when the long optical path is provided in air, a beam position and beam quality may deteriorate due to environmental changes such as fluctuation of air in the optical path, etc.

To circumvent this, as shown in FIG. 28, an optical path of the beam after going out of the A/O deflector 1301 is folded in a compact space by multiple times with folding mirrors 1302 and 1303 and further the space is sealed from the outside to construct a folding optics unit. By isolating this unit thermally from the outside using an insulating material, a heater for keeping the unit at a temperature higher than outer environment,

etc., problems of fluctuation in air and thermal deformation of optical components used are evaded, providing an optical path enabling to obtain a necessary scanning range securely.

As described in the foregoing, the laser beam scanning mechanism according to the present invention enables to perform high-speed and highly efficient laser beam scanning even in the deep ultraviolet region.

Next, referring to FIG. 29, an embodiment of defect detecting equipment equipped with a laser beam scanning mechanism selected from the first embodiment to the fifth embodiment described above will be described. This embodiment is constructed with an epi-illumination system as an illumination system. It is understood that the illumination system may be constructed with oblique illumination. Further, as an illumination light source 1, for example, a DUV (deep ultraviolet rays) laser (for example, KrF excimer laser=248 nm, ArF excimer laser=198 nm, etc.) is used. As described, a DUV (deep ultraviolet ray) laser beam has a shorter wavelength and hence high resolution, so that an optical image based on scattered light or diffracted light from a defect such as submicroscopic foreign particles having a dimension of 0. 1 μm or less etc. can be obtained.

Therefore, an illumination system 902 is constructed with: an illumination light source 910 such as a DUV laser etc.; a polarization control optical system for setting a polarization condition of the laser beam 104; a pupil scan illumination optical

system 904 consisting of either one of the above-described first to fifth embodiments for scanning a laser beam over the pupil 917 of the objective lens 122; and a half mirror (1)121. A basic construction of a detecting optical system 900 comprises: the objective lens 122; an imaging lens 912; a magnifying optical system 913; a polarization detecting optical system 914 for setting a polarization condition of detected light in front of an image sensor 915(801); and the image sensor 915(801) having DUV quantum efficiency of around 10% or more. By the way the polarization detecting optical system 914 in the detecting optical system 900 is to shield specula reflected light (zero-th order diffraction light) from the object (sample object) 204 and can be constructed with a spatial filter instead. In this case, instead of the polarization detecting optical system 903 in the illumination optical system 902, it is necessary to provide, for example, a ring-zone illumination optical system with the use of light sources arranged in an orbicular zone around a central axis of the optical system (secondary light source).

Further, a half mirror (2)921 is disposed on the way of a detection optical path and an automatic focusing system 922 for adjusting a surface of the sample object 204 on a focus of the objective lens 122 is arranged. Further, a half mirror (3)931 is disposed so as to construct an optical system capable of observing a position of the pupil of the objective lens 122 with a lens (1)932 and a pupil observation optical system 933. Further, a half

mirror (4)941 is disposed so as to construct an optical system capable of observing and aligning a pattern on the sample object 204 with a lens (2)942 and an alignment optical system 943.

Consequently, a DUV laser beam emitted from the illumination light source 910 is converted into linearly polarized light by, for example, the polarization control optical system 903 and scanned two-dimensionally over the pupil 917 of the objective lens 122 for performing irradiation by the pupil scan illumination optical system 904. The reflected light from the sample object 204 is transmitted through the half mirror (1)905 after passing through the pupil 917 of the objective lens 122 and forms an enlarged optical image of the sample 204 on the image sensor 915(801) through the imaging lens 912 and the magnifying optical system 913. By the way, the image sensor 915(801) can be configured to detect an image formed only with scattered light or a component of diffracted light from the surface of the sample object 204 by shielding a linearly polarized component of the specula reflected light (zero-th order diffraction component) from the sample object 204, for example, by means of the polarization detecting optical system 914.

Next, referring to FIG. 30, a signal processing system is described. That is, the signal processing system is composed of: an AD converter circuit 402 for analog-to-digital converting an image signal represented by grayscale values made of accumulation of signals from each column pixels which can be obtained from the

image sensor 915(801) composed of sensor elements having DUV quantum efficiency of around 10 % or more, for example the TDI image sensor, in synchronization with translation of the test object 204 in the Y-direction; a delay memory 403 for delaying a digital image signal outputted from the said AD converter circuit by the amount corresponding to, for example, 1 chip (or plural pitches) of a circuit pattern repeated in the Y-direction; a comparator circuit 404 for extracting a signal, for example a difference image signal, by comparing a digital detected image signal 408 obtained from the above-mentioned AD converter circuit 402 and a digital reference image signal 409 which was delayed by, for example, the amount of 1 pitch through the delay memory 403, and binarizing this extracted difference image signal using a predetermined threshold value to form a binarized image signal indicating defect candidates such as foreign particles, a circuit pattern defect, etc.; a feature quantity extracting circuit 405 for extracting a feature quantity of a defect candidate, such as an area, location coordinates, a maximum length (for example, projected lengths to the X-axis direction and the Y-axis direction), moment, etc. based on the binarized image signal obtained from the said comparator circuit 404 indicating defect candidates such as foreign particles etc.; and a defect judging circuit 406 for judging a defect candidate as a defect when the feature quantity of the said defect candidate extracted by the feature quantity extracting circuit 405 surpasses a

predetermined criterion. By the way, regarding the feature quantity, at a time when a certain feature is identified as a defect candidate, grayscale value based on a digital detected image signal obtained from the AD converter circuit 402 may be added to an original feature quantity to extract three-dimensional feature quantity.

Especially in order to detect a defect such as submicroscopic foreign particles of a size of around 0.1 μm or less etc., it is necessary to remove noise components due to minute irregularity of the surface and underlying pattern of the test object 204 out of the signal to prevent erroneous detection. For this end, a real submicroscopic defect such as foreign particles etc. can be detected through the steps of: extracting any difference image signal surpassing a predetermined threshold as a defect candidate; and discriminating whether an extracted signal is a true defect such as foreign particles etc. or false information arising from minute irregularity of the surface or an underlying pattern according to the extracted feature quantity of each defect candidate.

According to the present invention, since a UV laser or DUV laser beam of a short wavelength can be used after its coherence is reduced, a defect of a circuit pattern having a pattern width as small as 0.2 μm or less can be detected with sufficient accuracy.

By virtue of the present invention, since high-illuminance UV light emitted from a laser source can be used to irradiate a sample after its coherence was reduced, a higher-resolution image can be obtained compared to a case where conventional visible light is used as illumination light, and hence a defect can be detected with high sensitivity.